README File

NMMIEAI-L2 V2.1.1

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1. Overview

The purpose of this document is to provide an overview of the NASA OMPS-NPP UV Aerosol Index (UVAI) product generated by the NMMIEAI-L2 algorithm (version 2.1.1) using 340 and 378.5 nm radiances from the OMPS Nadir Mapper (NM) onboard NOAA's Suomi-NPP spacecraft. Along with the description of the data product, the algorithm is briefly described.

The UVAI is a residual parameter that quantifies the difference in spectral dependence between measured and calculated outgoing near UV radiances at the top of the atmosphere (TOA) assuming a model atmosphere in which Rayleigh scattering is explicitly accounted for, and cloud scattering effects are parameterized. The resulting residual quantity is calculated with the expression

$$r_\lambda = -100\left\{\log\left[\frac{I_\lambda^{obs}}{I_{\lambda_0}^{obs}}\right] - \log\left[\frac{I_\lambda^{cal}}{I_{\lambda_0}^{cal}}\right]\right\} \quad (1)$$

In the above definition, λ and λ_0 are in the range 330 to 390 nm. Generally, λ_0 (larger than λ) is the reference wavelength used for the calculation of the scene reflectivity or cloud fraction terms as discussed in section 2.

The way the calculated terms in Equation 1 is obtained, has evolved since the introduction of the AI concept [Herman et al., 1997]. Torres et al [2018], describes the approaches historically used in the estimation of the calculated radiances..

Because most of the observed residuals are associated with the presence of absorbing aerosols, this parameter is commonly known as the UV Aerosol Index. The UVAI has become an invaluable tool for tracking long-range transport of absorbing aerosols (smoke and dust) throughout the globe, even when the aerosols are over clouds. The UVAI has been instrumental in the discovery of important aspects of aerosol transport both horizontally and vertically. For instance, UVAI observations indicate that smoke aerosol plumes generated by boreal forest fires at mid and high latitudes are associated with the formation of pyro-cumulonimbus clouds capable of transporting carbonaceous aerosols to the lower stratosphere.

Effective this release, the NMMIEAI UVAI becomes the official NASA Aerosol Index product, replacing the NMTO3-generated product which will no longer be produced in the Version 9 of the NMTO3 algorithm.

The first OMPS NM Earth View (EV) measurements used to create the NMEV-L1B product were taken on January 28, 2012. Data for February-March 2012 have numerous gaps due to variations in instrument. Regular operations began on April 2, 2012 with approximately 50 km x 50 km at nadir. Note that the OMPS NM conducted high-resolution measurements approximately 10 km x 10 km at nadir one day per week for the first two years of mission.

The information in this README file applies only to the public release of the NMMIEAI UVAI data from NMEV-L1B (version 2.0) files. As subsequent data versions are produced and released, the README file will be updated accordingly to reflect the latest algorithm modifications and data quality.

2. V2.1.1 NMMIEAI Algorithm Description

The NMMIEAI algorithm currently uses the measurements made at two wavelengths: 340 and 378.5 nm. This is partly to maintain heritage with similar algorithm used for TOMS [*Torres et al.,* 1998], and partly because of a lack of reliable calibrated data at the longer OMPS wavelengths.

2.1. Surface Albedo

Global climatological data sets of Lambertian surface reflectivity (R_{SFC}) at 331, 340, 360, and 380 nm are used to account for surface effects in the algorithms. It was obtained using a multi-year record of scene reflectivity (R_{SCE}) obtained from N7-TOMS observations. For a Lambertian reflecting surface the satellite measured radiance at the top of the atmosphere can be estimated using the Chandresekar approximation (Equation 2),

$$I^{obs} = I^0 + \frac{RT}{1 - S_b R} \quad (2)$$

where I^{obs} represents the satellite measured radiance and, I^0, T, and S are respectively the modeled path radiance, the two-way transmittance, and the spherical albedo of a molecular atmosphere, and R is simply the Lambertian reflectivity of the of bottom of the atmospheric column that in addition to the actual surface, also includes clouds and aerosol effects. Scene Lambert Equivalent Reflectivity (LER) values at 331, 340, 360, and 380 nm (R_{SCE}) are calculated at every Nimbus 7 TOMS pixel for a purely molecular atmosphere model solving for the R term in Equation 2 yielding

$$R_{SCE} = \frac{I^{obs} - I^0}{T + S(I^{obs} - I^0)} \quad (3)$$

Multi-year long R_{SCE} records from N7-TOMS (1979-1992) observations have been used to create monthly climatologies of surface reflectivity (R_{SFC}) using the approach described below. This approach is essentially same as by Herman and Celarier [1997], but accounting for wavelength dependence and ocean angular effects.

Over land, monthly R_{SFC} values are estimated as the minimum observed R_{SCE} over the multi-year TOMS records. Resulting values for every month of the year averaged over a 1.0° x 1.0° geographical grid.

The ocean surface reflectivity is estimated in a similar way as over land with the addition of a correction for the Sun's specular reflection. The satellite derived R_{SCE} under cloud-free conditions over the ocean is approximated as the sum of two terms: a Lambert-equivalent Fresnel reflectivity (R_F) term and a second reflectivity term associated with water-leaving reflectance (R_W). The R_F term is obtained by calculating the upwelling radiance at the top pf the atmosphere using an atmosphere-ocean radiative transfer model [*Cox and Munk*, 1954] for a chlorophyll-free ocean. The calculated radiance is then converted to LER using an equation similar to Eq. 1, in which the calculated radiance is used in lieu of the observed one. The R_F thus calculated varies with solar zenith, view zenith and azimuth angles. R_W is estimated empirically by subtracting R_F from R_{SCE}. The resulting minimum R_W values per grid per month are assumed here to represent the ocean R_{SFC}.

2.2. Radiance Calculation

The calculated radiances in Equation 1 are obtained by assuming that the radiance measured by the sensor at pixel level emanates from a combination of clear and cloudy conditions (I_λ^s and I_λ^C) involving a cloud of fixed optical depth and varying cloud fraction [Torres et al., 2018]. The I_λ^s term is calculated from the Chandresekar equation using as input the wavelength dependent climatological values of surface albedo (derived as explained in Section 2.1) and a pure molecular atmospheric model for surface pressured adjusted for topography. The I_λ^C terms, on the other hand, are calculated using Mie scattering theory for an assumed water cloud model [*Deirmendjian,* 1964] and wavelength-dependent refractive index [*Hale and Querry*, 1973], at prescribed top and bottom levels (700 and 800 hPa), and fixed cloud optical depth (COD) of 10. The choice of COD value of 10 is based on the highest frequency of occurrence of this value reported by MODIS observations [*King et al.,* 2013]. A wavelength independent cloud fraction, f_C, is calculated from equation

$$f_C = \frac{I_{\lambda_0}^{obs} - I_{\lambda_0}^{s}}{I_{\lambda_0}^{C} - I_{\lambda_0}^{s}} \quad (4)$$

When the resulting cloud fraction is larger than unity, overcast sky conditions are assumed (i.e., $f_C=1.0$), and a new I_λ^C term for COD value larger than 10 that matches $I_{\lambda_0}^{obs}$ is derived. I_λ^{cal} values are then obtained by linearly combining the clear and cloudy sky contributions:

$$I_\lambda^{cal} = (1.0 - f_C) I_\lambda^s + f_C I_\lambda^C \quad (5)$$

For snow/ice conditions and high terrain surfaces (< 600 hPa), a Lambertian reflectivity term is calculated as

$$R_{\lambda_0} = \frac{I_{\lambda_0}^{obs} - I_{\lambda_0}^{0}}{T_{\lambda_0} + S_{\lambda_0}(I_{\lambda_0}^{obs} - I_{\lambda_0}^{0})} \quad (6)$$

The terms in Eq. 6 have been defined in Section 2.1. The calculated radiance at each wavelength is then obtained from the expression

$$I_{\lambda}^{cal} = I_{\lambda}^{0} + \frac{R_{\lambda_0} T_{\lambda}}{1 - S_{\lambda} R_{\lambda_0}} \quad (7)$$

where a wavelength-independent Lambertian reflectivity has been assumed. The output of this calculation is then fed into Eq. 3 to calculate UVAI. If a snow or ice fraction is available, UVAI is calculated as a weighted combination of the resulting UVAI's using Equations 5 and 7 for obtaining the calculated component [*Torres et al.,* 2018].

Near-zero values of UVAI result when the radiative transfer processes accounted for in the simple Rayleigh scattering model adequately explain the observations. For a well-calibrated sensor, the non-zero UVAI values are produced solely by geophysical effects, of which absorbing aerosols are by far the most important. Non-absorbing aerosols yield small negative UVAI values but the difficulty to separate the non-absorbing aerosol signal from other non-aerosol related effects limits its usefulness.

The LER based AI assuming a wavelength independent LER at 378.5 nm is also reported as "Residue" and Mie-cloud based AI is reported as "UVAerosolIndex" in NMMIEAI-L2 files.

3. Product Description

The NMMIEAI-L2 data files are provided in the HDF5 format (Hierarchical Data Format Version 5), developed at the National Center for Supercomputing Applications (https://www.hdfgroup.org/). These files use the Swath data structure format that follows a specific file naming convention and dataset organization.

3.1. File naming convention

The components of file names are as follows:

OMPS-NPP_NMMIEAI-L2_pXXX_observationDate_productionTime.**h5**

XXX = 3-digit processing identifier (PID), [000, 080, 160, 161, 168, 172]
observationDate = start date of measurements in YYYY**m**MMDD_**o**ZZZZZ format

- YYYY = 4-digit year number [2012-current].

- MM = 2-dgit month number [01-12].
- ZZZZZ = 5-digit orbit number

productionTime = file creation stamp in YYYY**m**MMDD**t**hhmmss format

- hhmmss= hour(hh), minute(mm), and second(ss) in local time

File name example:
OMPS-NPP_NMMIEAI-L2-p000_2015m0505t000144_o18226_2018m0226t162448.h5

3.2. Data contents

Note that the following description of file structure and contents are valid only for the files with PID of "000" (= regular mode) having appropriate calibration adjustments (i.e., soft calibration). Files with other PIDs are processed but data quality is not compatible with that of PID "000".

The top-most level in the HDF5 hierarchy of NMMIEAI-L2 files contains three different directories, one for each type of pixel-dependent data: CalibrationData (containing data used to adjust calibrated radiances), GeolocationData (containing data to geolocate each pixel, as well as viewing angle information), and ScienceData/Pair340_379 (containing the calibrated radiances , Reflectivity, UVAI, Residue, Cloud Fraction, and Cloud Optical Depth).

NMMIEAI-L2 includes the following dimension terms:

- DimAlongTrack = Along-track dimension (400)
- DimCrossTrack = Across-track dimension (36)
- DimCorners = Latitude and Longitude corner bound dimension (4)
- DimWavelength = Dimension for four wavelengths (340, 342.5, 354, and 378.5 nm)
- DimWavelengthPair = Dimension for two wavelengths (340 and 378.5 nm)

The key data fileds most likely to be used by typical users are listed below with path directories and dimensions:

/BinScheme1/GeolocationData/Latitude [DimAlongTrack, DimCrossTrack]
/BinScheme1/GeolocationData/LatitudeCorner [DimAlongTrack, DimCrossTrack, DimCorners]
/BinScheme1/GeolocationData/Longitude [DimAlongTrack, DimCrossTrack]
/BinScheme1/GeolocationData/LongitudeCorner [DimAlongTrack, DimCrossTrack, DimCorners]

/BinScheme1/ScienceData/Pair340_379/CloudFraction [DimAlongTrack, DimCrossTrack]
/BinScheme1/ScienceData/Pair340_379/CloudOpticalDepth [DimAlongTrack, DimCrossTrack]
/BinScheme1/ScienceData/Pair340_379/Reflectivity [DimAlongTrack, DimCrossTrack, DimWavelengthPair]
/BinScheme1/ScienceData/Pair340_379/Residue [DimAlongTrack, DimCrossTrack]
/BinScheme1/ScienceData/Pair340_379/UVAerosolIndex [DimAlongTrack, DimCrossTrack]

A complete list of the parameters is as follows:

CalibrationDataGroup

Dataset Name	Description	Dimensions	Units
NValueCorrection	Soft calibration in N-value [-100*log10(normalized radiance)]	DimCrossTrack, DimWavelength	No unit

GeolocationDataGroup

Dataset Name	Description	Dimensions	Units
CERESSurfaceCategory	IGBP 18 category legends	DimAlongTrack, DimCrossTrack	No unit
GroundPixelQualityFlags	Bit packed ground pixel quality flag	DimAlongTrack, DimCrossTrack	No unit
InstrumentQualityFlags	Bit packed error flag	DimAlongTrack, DimCrossTrack	No unit
Latitude	Ground pixel latitude	DimAlongTrack, DimCrossTrack	Degrees
LatitudeCorner	Ground pixel latitude corners	DimAlongTrack, DimCrossTrack, DimCorners	Degrees
Longitude	Ground pixel longitude	DimAlongTrack, DimCrossTrack	Degrees
LongitudeCorner	Ground pixel longitude corners	DimAlongTrack, DimCrossTrack, DimCorners	Degrees
RelativeAzimuthAngle	Difference between viewing and solar azimuth angle	DimAlongTrack, DimCrossTrack	Degrees
SatelliteAzimuthAngle	Satellite azimuth angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SatelliteZenithAngle	Satellite zenith angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SolarAzimuthAngle	Solar azimuth angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
SolarZenithAngle	Solar zenith angle of each pixel	DimAlongTrack, DimCrossTrack	Degrees
Time_TAI93	TAI93 time of measurement (number of seconds since 1 January 1993)	DimAlongTrack	Seconds
UTC_CCSDS_A	Twenty-seven character UTC date-and-time string	DimAlongTrack	No unit

ScienceData/Pair340_379 Group

Dataset Name	Description	Dimensions	Units
AlgorithmFlags_AerosolIndex	Bit packed flags for Aerosol Index	DimAlongTrack, DimCrossTrack	No unit
BandCenterWavelengths	Actual band center wavelengths for 340 and 378.5nm	DimAlongTrack, DimCrossTrack, DimWavelengthPair	nm
CloudFraction	Effective cloud fraction of each pixel	DimAlongTrack, DimCrossTrack	No unit
CloudOpticalDepth	Cloud optical Depth of each pixel	DimAlongTrack, DimCrossTrack	No unit
DimWavelengthPair	Two wavelengths (340 and 378.5 nm)	DimWavelengthPair	nm
NormalizedRadiance	Ratio of radiance to irradiance for each pixel	DimAlongTrack, DimCrossTrack, DimWavelengthPair	No unit
PixelQualityFlags	Bit packed quality flag	DimAlongTrack, DimCrossTrack, DimWavelengthPair	No unit
Radiance	NMEV-L1B radiance of each pixel	DimAlongTrack, DimCrossTrack, DimWavelengthPair	w/cm^3/strad
Reflectivity	Lambertian equivalent reflectivity (LER)	DimAlongTrack, DimCrossTrack, DimWavelengthPair	No unit
Residue	LER derived Aerosol Index	DimAlongTrack, DimCrossTrack	No unit
SnowIceFraction	Snow/ice fraction of each pixel	DimAlongTrack, DimCrossTrack,	No unit
SolarFlux	NMEV-L1B irradiance of each pixel	DimCrossTrack, DimWavelengthPair	w/cm^3/strad
SurfaceAlbedo	N7-TOMS derived surface albedo	DimAlongTrack, DimCrossTrack, DimWavelengthPair	No unit
TerrainPressure	Terrain pressure of each pixel	DimAlongTrack, DimCrossTrack	hPa
UVAerosolIndex	Mie cloud based Aerosol Index	DimAlongTrack,	No unit

		DimCrossTrack	

Contacts for further detailed information of parameters and their usages are listed below.

4. Contacts

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